Respiratory responses in heat-exposed rabbits: Inhibition of Tachypnoea offset by increase in tidal volume

M. Maskrey

Department of Physiology, University of Tasmania, G.P.O. Box Number 252C, Hobart, Tasmania, 7001 (Australia),
6 September 1976

Summary. Rabbits in which thermal panting has been inhibiting by previous cold exposure or by water deprivation respond to a raised ambient temperature with an increase in tidal volume. By so doing, they are able to maintain a minute volume appropriate to their thermoregulatory requirements.

Thermal panting is generally characterised by rapid, shallow breathing[1]. This implies an increase in respiratory frequency (RF) and a decrease in tidal volume (V_T). As a rule, the increase in RF outweighs the fall in V_T so that minute volume (V_E) increases, as also does respiratory evaporative heat loss (E_{ex}). Thus regulation of E_{ex} has become equated with the regulation of RF. In the rabbit, RF normally increases with increasing ambient temperature (T_a) above 25 °C[2]. However, the increase in RF in response to a high T_a is inhibited in rabbits which have been water deprived or previously exposed to cold[3]. At 35 °C, tachypnoea usually remains inhibited for about 30 min. During this time, the lower RF is accompanied by a higher V_T so that V_E is similar in treated and control animals[4]. Moreover, the increase in T_{re} during 1 h at 35 °C is no greater in treated rabbits than in controls[3,4]. The implication from this is that under some circumstances the rabbit can maintain V_E at an appropriate level to meet thermoregulatory demands by increasing V_T instead of RF. This situation has so far been described only in the case of the ostrich[5]. In the present report the implication is explored further.

5 New Zealand White rabbits weighing between 2.5 and 4.5 kg were clipped of most of their fur and exposed in turn to each of the 3 following conditions. Prior to an experiment, the animals were either kept at 20 °C with water available ad libitum (control), or they were exposed for 24 h to a T_a of 5 °C, again with water available ad libitum (cold-exposed) or they were kept at 20 °C but

1 S. A. Richards, Biol. Rev. *45*, 223 (1970).
2 R. R. Gonzalez, M. J. Kluger and J. D. Hardy, J. appl. Physiol. *31*, 728 (1971).
3 M. Maskrey and S. C. Nicol, J. Physiol., Lond. *252*, 481 (1975).
4 M. Maskrey and S. C. Nicol, J. Physiol., Lond. *261*, 375 (1976).
5 E. C. Crawford and K. Schmidt-Nielsen, Am. J. Physiol. *212*, 347 (1967).

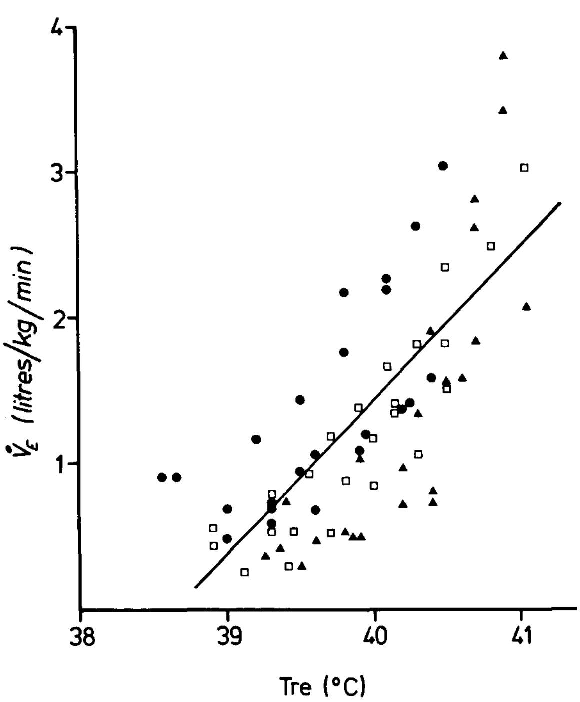

Fig. 1. The relationship between rectal temperature (T_{re}) and minute volume (V_E) in control (●), cold-exposed (□) and water-deprived (▲) rabbits during exposure to 35 °C. r = 0.75.

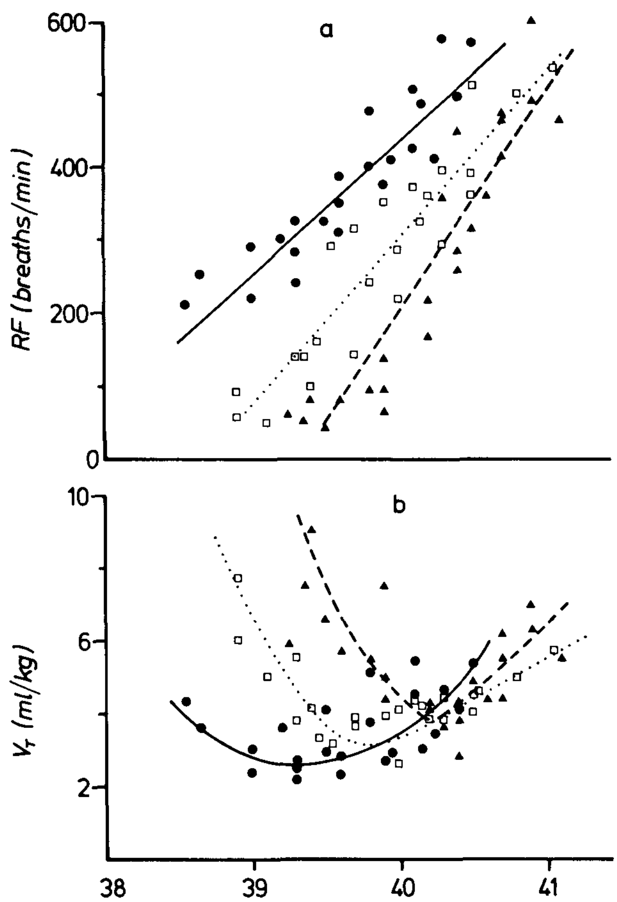

Fig. 2. *a* The relationship between rectal temperature (T_{re}) and respiratory frequency (RF) in rabbits exposed to 35 °C. Symbols as in figure 1. r = 0.92, 0.90 and 0.92 respectively for control, cold-exposed and water-deprived animals. *b* The relationship between rectal temperature (T_{re}) and tidal volume (V_T) in rabbits exposed to 35 °C. Symbols as in figure 1.

deprived of drinking water for 72 h (water-deprived). In the experiments rabbits were exposed for 1 h to a T_a of 35 °C. T_{re} and oxygen consumption (V_{O_2}) were monitored continuously. Respiratory volumes and frequencies were measured at 10-min-intervals using the barometric technique of Drorbaugh and Fenn[6].

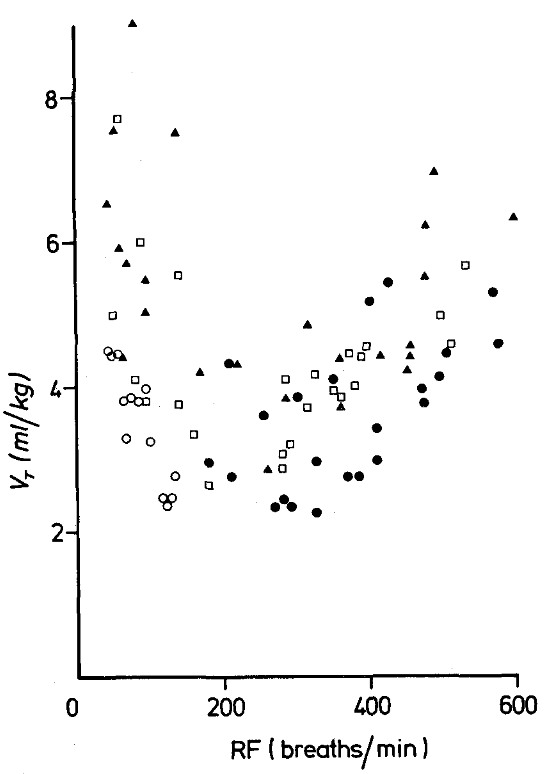

Fig. 3. The relationship between respiratory frequency (RF) and tidal volume (V_T) in rabbits exposed to 35 °C (symbols as in figure 1) and to temperatures within the thermoneutral range (○).

Figure 1 demonstrates the correlation between T_{re} and V_E. Differences between the 3 conditions are not significant, thus it appears that V_E is always regulated at a level appropriate to a given core temperature. RF increases with increasing T_{re} (figure 2a). V_T initially decreases with increasing T_{re} then increases with a further rise in T_{re} (figure 2b). The minimum V_T for control, cold-exposed and water-deprived rabbits occurs at rectal temperatures of 39.3, 39.8 and 40.2 °C respectively. At these rectal temperatures, the corresponding respiratory frequencies average 300, 250 and 265 breaths/min. Plotting RF against V_T (figure 3) confirms that V_T is lowest in the RF range 250–300 breaths/min. Above this range, thermoregulatory demands dictate that both RF and V_T increase in order than V_E be maintained at the appropriate level. Below RF = 250 it might be argued that V_T is physically dependent upon RF such that a low RF will inevitably lead to a high V_T. To test this possibility, the same rabbits were exposed to ambient temperatures within their thermoneutral range (T_a 21–27 °C). In these experiments RF varied over a range of between 45 and 135 breaths/min but although the trend is still for V_T to be higher for a lower RF, mean V_T remains significantly lower than in blocked rabbits at the corresponding frequencies when exposed to 35 °C ($p < 0.001$) (see figure 3). Moreover, this difference could not be explained in terms of a change in metabolic requirements as the difference in V_{O_2} between the animals at 35 °C and at thermoneutrality was not great enough to account for the difference in V_T. Thus the conclusion is reached that in the rabbit the thermoregulatory drive is so powerful that when an increase in RF in the heat is specifically inhibited by water deprivation of prior cold exposure, then V_E, and presumably E_{ex}, can be increased through a rise in V_T.

6 J. E. Drorbaugh and W. O. Fenn, Pediatrics *16*, 81 (1955).

Electrotonic synapses in the visceral ganglion of Planorbis[1]

V. W. Pentreath[2] and M. S. Berry

Wellcome Laboratories of Pharmacology, Gatty Marine Laboratory, The University of St. Andrews, St. Andrews (Scotland),
24 August 1976

Summary. In the visceral ganglion of Planorbis the postsynaptic neurones of the characterized dopamine neurone are connected by non-rectifying electrotonic junctions. The coupling, which is reduced by stimulation of the dopamine neurone and by applied dopamine, may be important in the generation of burst activity. Specialized areas of close apposition of membranes in the neuropile are considered to be the morphological correlate of electrotonic coupling.

In the left pedal ganglion of the water snail Planorbis corneus there is a specified dopamine neurone which makes monosynaptic connexions with certain neurones in the visceral and parietal ganglia[3,4]. The input from the dopamine neurone is inhibitory to the visceral neurones and excitatory to the parietal neurones. The visceral neurones (of which there are at least 15) have been found to be coupled electrically. This paper describes some aspects of the coupling and also its presumed morphological correlate. *Materials and methods.* The isolated ganglionic ring was immersed in physiological saline[5] at room temperature (20 °C). Double barrelled microelectrodes containing 0.6 M K_2SO_4 were used for intracellular recording and stimulation. The recording and stimulating equipment was conventional. For electron microscopy the visceral ganglion was fixed in buffered glutaraldehyde and osmium solutions[6]. Sections were stained with lead citrate

1 This work was supported by grants from the S. R. C. and M. R. C. to Dr G. A. Cottrell, whose help is gratefully acknowledged.
2 Present address: Department of Biology, University of Salford, Salford, M5 4WT.
3 M. S. Berry and G. A. Cottrell, Nature New Biol. *242*, 250 (1973).
4 M. S. Berry and G. A. Cottrell, J. Physiol., Lond. *244*, 589 (1975).
5 M. S. Berry, J. exp. Biol. *56*, 621 (1972).
6 V. W. Pentreath, M. S. Berry and J. L. S. Cobb, Cell Tiss. Res. *163*, 99 (1975).